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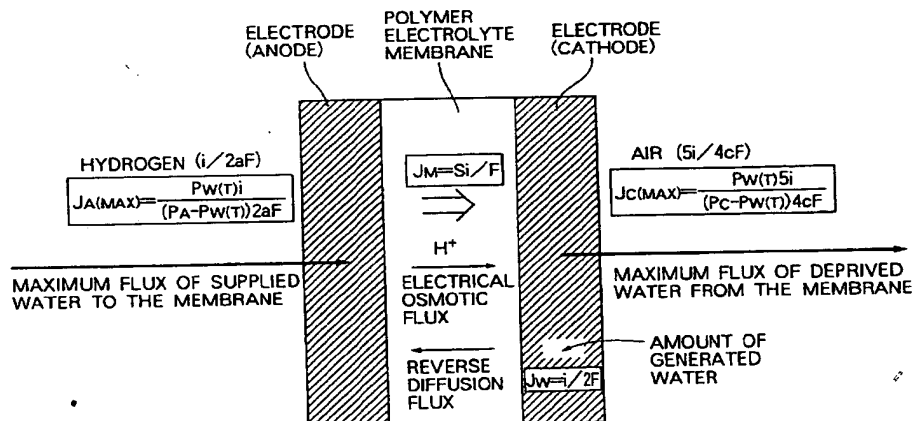
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(54) Polymer electrolyte fuel cell with internal humidification

(57) A polymer electrolyte fuel cell comprising a polymer electrolyte membrane, an anode catalytic electrode disposed at one side of the polymer electrolyte membrane, a fuel gas being supplied to the anode catalytic electrode, a cathode electrode disposed at another side of the polymer electrolyte, an oxidation gas being supplied to the cathode catalytic electrode, control means for controlling a reduction amount of water from the cathode electrode accompanying with the ox-

dation gas to a sum of a water amount increased at the cathode electrode transported from the anode electrode through the polymer electrolyte membrane during a redox reaction of the fuel cell and a water amount produced by an oxidation reaction in the cathode electrode. A compact fuel cell system with a high cell performance can be accomplished.

FIG. 2



S: NET FLUX OF WATER PER A MOLE OF ELECTRONS
F: FARADAY CONSTANT
i: CURRENT DENSITY
a: UTILIZATION FACTOR OF HYDROGEN

c: UTILIZATION FACTOR OF AIR
P_A: TOTAL PRESSURE OF ANODE SIDE (HYDROGEN)
P_C: TOTAL PRESSURE OF CATHODE SIDE (AIR)
P_W(T): SATURATION VAPOR PRESSURE AT TEMP. OF T(°C)

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a polymer electrolyte fuel cell, in particular, a water supply to a polymer electrolyte membrane of the fuel cell.

Related Art

A polymer electrolyte fuel cell is possible to be operated around the atmospheric temperature to accomplish a high energy conversion efficiency and power output efficiency or a cell performance. As a result, the polymer electrolyte has been highlighted recently as a movable power resource or power source of an electric automobile.

The polymer electrolyte fuel cell comprises an electricity generating element constituted by sandwiching a polymer electrolyte membrane having a hydrogen ion conductivity with carbon electrolytes carrying platinum catalyst, or a polymer electrolyte membrane-electrolyte joiner. Then, gas passages are formed across each surface of the electrodes for supplying reaction gases therethrough respectively. The electricity generating element is supported by gas separators at opposite sides to form a laminated structure of the polymer electrolyte fuel cell. Then, a hydrogen gas or fuel gas is supplied to one of the electrodes and an oxygen gas or air, namely, oxidizing gas to the other electrodes to obtain an electro-chemical energy due to a redox reaction of the reaction gases as an electric energy directly. In this case, the hydrogen gas at an anode side is ionized and moved through the polymer electrolyte, on the other hand, the electron is moved to a cathode side through an external load to react with the oxygen to produce a water. Thus, the electric energy due to the electro-chemical reaction can be taken out. The hydrogen ion is moved through the polymer electrolyte membrane accompanying a water molecule. Accordingly, if the polymer electrolyte membrane is dried out, the ion conductivity thereof will be remarkably reduced to thereby reduce the energy conversion efficiency. In view of this, in order to maintain a good ion conductivity, it is necessary to supply the water to the polymer electrolyte membrane. To this end, conventionally, there has been provided a humidifier for humidifying the fuel gas and oxidation gas.

Taking reference with Figure 1, there is shown a conventional fuel cell system 1 schematically.

In the system 1, there is provided a fuel cell stack 2 in which a plurality of the polymer electrolyte fuel cell unit are laminated. To the anode sides of the fuel cell stack 2 is supplied the hydrogen gas as a fuel gas through a supply tube 3. The air as an oxidation gas is supplied to the respective cathode sides of the stack 2

though an air supply tube 4. In order to control pressures of the hydrogen and air, regulators 5 and 6 are provided. Pressure indicators 7 and 8 are provided for detecting the supply pressures. In addition, there are provided hydrogen and air humidifiers 9 and 10 respectively for humidifying the supply gases in the respective gas supply systems so that the supply gases accompanying certain humidity are supplied to the stack 2.

In addition, flow control valves 13 and 14 are provided in air and hydrogen exhaust tubes 11 and 12 from the fuel cell stack 2.

The fuel cell system 1 is provided with a temperature control mechanism for controlling the temperature in the system by means of the supply of a cooling water to the stack 2. The temperature control mechanism includes a heat exchanger 15, cooling water tank 16 and a cooling water circulation pump 17. A thermocouple 19 is disposed in a cooling water circulation line 18 to measure the temperature therein.

Meanwhile, when the air is employed for the oxidation gas, an air compressor (not shown) is necessary for pressurizing the air to a desirable pressure.

When the fuel cell is desired to apply for the power source of a vehicle as the automobile, a compact fuel cell system is required to save a space. In this case, it is necessary to provide a compact fuel cell system including the peripheral systems such as the air compressor, and humidifier as a whole.

Therefore, an object of the invention is to provide a compact fuel cell system.

In particular, an object of the invention is to provide a compact fuel cell system as whole by providing a compact humidifier for the oxidation gas.

The above and other objects of the present invention can be accomplished by a polymer electrolyte fuel cell comprising a polymer electrolyte membrane, an anode catalytic electrode disposed at one side of the polymer electrolyte membrane, a fuel gas being supplied to the anode catalytic electrode, a cathode electrode disposed at another side of the polymer electrolyte, an oxidation gas being supplied to the cathode catalytic electrode, control means for controlling a reduction amount of water from the cathode electrode together with the oxidation gas to a sum of a water amount increased at the cathode electrode by being transported from the anode electrode through the polymer electrolyte membrane during a redox reaction of the fuel cell and a water amount produced by an oxidation reaction in the cathode electrode.

Preferably, the polymer electrolyte membrane has a thickness from about 20 -80 μm more preferably, about 20-50 μm .

In preferred embodiment, an operating temperature of the fuel cell is maintained from about 50 $^{\circ}\text{C}$ to 80 $^{\circ}\text{C}$, preferably 60 $^{\circ}\text{C}$ -70 $^{\circ}\text{C}$. As a result, the water level at the cathode side can be maintained at a desirable condition.

Preferably, the fuel gas is a hydrogen and the oxida-

tion gas is an air. In the present invention, there is no humidifier for humidifying the oxidation gas. thus, a compact fuel cell system as a whole can be facilitated remarkably.

Preferably, a thickness of the catalyst layer in the electrolyte membrane is less than about 10 μm .

The polymer electrolyte membrane enable protons or hydrogen ions to be transported when it includes a sufficient water so that the an external electric circuit is formed. Thus, the fuel cell which performs an external work can be formed. Namely, in order to form the fuel cell, the polymer electrolyte membrane is needed to contain a sufficient water. At the cathode electrode of the polymer electrolyte, the water is produced due to the oxidation reaction. However, if the water product is excessive at the cathode electrode, the output performance of the fuel cell is deteriorated.

Accordingly, in order to maintain a desirable cell performance, the produced water is to be properly excluded from the cathode electrode and thus from the fuel cell system. In short, both a short water condition of the polymer electrolyte and an excessive water condition of the cathode electrode will deteriorate the output performance of the fuel cell system. In addition, the water amount contained in the fuel gas and the oxidation gas it to be maintained properly.

With regard to a water transportation in the polymer electrolyte, there are two types of the water transportation. one is a so called electrical osmotic flux in which a water is transported from the anode to cathode accompanying the proton transportation. The other is a reverse water diffusion flux in which the water is transported from the cathode to the anode. Accordingly, a water balance in the polymer electrolyte depends on the respective amounts of the electrical osmotic flux and the reverse diffusion flux. Generally, in order to balance the electrical osmotic flux with the reverse diffusion flux, it is necessary to humidify the hydrogen gas at the anode electrode to supply a certain amount of water. On the other hand, if the air is employed for the oxidation gas, the air of 2.5 times amount of the hydrogen flux in the anode side stoichiometrically. Thus, if the gas utilization rates are the same for the respective electrodes, the 2.5 times water accompanying the air is taken away from the cathode side compared with the anode side.

At the cathode side, the water is produced by the oxidation reaction and the electrical osmotic flux over the reverse diffusion flux is flew in and increased compared with the anode side. However, the gas flow in the cathode side are greater than the anode side. As a result, a water shortage condition is produced in the cathode side. Conventionally, the humidifier is provided for dealing with this water shortage condition in the cathode side.

The inventors of the present invention found that a desirable output performance of the fuel cell can be maintained regardless of the omission of the air humidifier of the air.

There is shown a model a water transportation on the polymer electrolyte membrane. The amount of the water transportation in the polymer electrolyte membrane is a difference between the electrical osmotic flux and the reverse diffusion flux and thus can be expressed by the following equation.

$$J_M = Si/F \quad (F: \text{Faraday constant}) \quad (1)$$

wherein

J_M : Amount of water transportation through the membrane
 S : Net flux of water per a mole of electrons
 i : Current density

The water amount produced in the cathode side J_W can be expressed as;

$$J_W = i/2F \quad (2)$$

Maximum flux of supplied water to the membrane at the anode side $J_{A(\text{MAX})}$ can be shown by the following equation.

$$J_{A(\text{MAX})} = (P_{W(T)} / (P_A - P_{W(T)})) i / 2aF \quad (3)$$

Wherein

a : Utilization factor of hydrogen
 P_A : Hydrogen supply pressure
 $P_{W(T)}$: Saturation vapor pressure at temp. of $T(^{\circ}\text{C})$

Maximum amount $J_{C(\text{MAX})}$ of the water amount taken away from the cathode side can accompany the air J_C can be expressed as follows:

$$J_{C(\text{MAX})} = (P_{W(T)} / (P_C - P_{W(T)})) 5i / 4cF \quad (4)$$

Wherein

c : Utilization factor of air
 P_C : Air supply pressure.

During the redox reaction of the fuel cell, it is crucial that the sum of the water transportation amount J_M from the anode side to the cathode side through the polymer electrolyte membrane and the water amount produced in the cathode electrode J_W due to the oxidation reaction is balanced with the water amount J_C taken away from the cathode side accompanying the air. It is also crucial that the water amount J_M transported through the polymer electrolyte is balanced with the water supply amount J_A to the anode side.

If the water amount J_C taken away from the cathode

is greater than the sum of the water transportation amount J_M and the produced water amount J_W , it is impossible to maintain a desirable water amount at the cathode side. Namely, a dry out phenomenon occurs at the cathode side.

If the water supply amount J_A to the anode side is smaller than the water transportation amount J_M , the dry out phenomenon occurs at the anode side.

In both cases, the cell performance is deteriorated. The maximum amount $J_{C(MAX)}$ of the water amount taken away from the cathode side accompanying the air J_C and the maximum flux $J_{A(MAX)}$ of supplied water J_A to the membrane at the anode side are the saturated vapor water amounts respectively at a temperature. Thus, the maximum amounts $J_{C(MAX)}$ and $J_{A(MAX)}$ depend on the temperature and thus as the temperature increases, they increase remarkably. Similarly, the amounts J_C and J_A also increase remarkably as the temperature increases. As a result, where the temperature of the air supply is high, the dry out tends to occur at the cathode side. In order to prevent such dry out, it is desirable to operate the fuel cell at a low temperature so that the humidification amount of the air can be reduced. Where the temperature of the supply gas is low, the supply water amount J_A and the transportation water amount J_M are substantially balanced at the anode side. Where the temperature decreases beyond a certain level, the supply water amount J_A becomes smaller than the water transportation amount J_M and thus the dry out problem occurs.

Meanwhile, as the thickness of the polymer electrolyte membrane is reduced, the reverse diffusion flux is increased. Thus, the transportation water amount is reduced as a whole. It is considered that this is because a gradient of the water density becomes abrupt in the membrane between the anode and cathode sides. Accordingly, it is desirable to reduce the thickness of the membrane in order to prevent the dry out at the anode side which is caused due to the reduction of the water supply amount J_A at the anode side during the low temperature operation.

Further objects, features and advantages of the present invention will become apparent from the Detailed Description of Preferred Embodiments which follows when read in light of the accompanying Figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic view of a conventional fuel cell system as a whole;

Figure 2 is a view for explaining a water transportation model in the fuel cell;

Figure 3 is a view showing a temperature dependency of the water transportation amount;

Figure 4 is a view showing an output voltage characteristic of the fuel cell as the operating temperature and the gas flow rate are changed;

Figure 5 is a view showing an internal resistance

characteristic of the polymer electrolyte membrane as the gas flow rate is changed;

Figure 6 is a schematic view of a fuel cell system in accordance with the present invention;

Figure 7 is a view showing a relationship between the electric current and the fuel cell output characteristics as the operating temperature is changed; Figure 8 is a view showing relationships between the electric current and the fuel cell output voltage in an air humidification operation and a non-humidification operation;

Figure 9 is a view showing output characteristics of the fuel cell in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figure 3, there are shown relationships between the water transportation amount J_M , the maximum water supply amount $J_{A(MAX)}$ at the anode side and the maximum water amount $J_{C(MAX)}$ removed from the cathode side with regard to the temperature.

The water transportation amount was obtained based on the net flux of water per mole of electrons S which is cited from an article entitled as "a water transportation during an operation of the polymer electrolyte fuel cell" by Mizuhata et al. Collections of Abstracts of The 61th Meeting of Electro-Chemical Association in 1994. The value of S below 60 °C is substituted by the value S at 70 °C.

From these relationships, it is found that a desirable water balance in the fuel cell can be obtained at a temperature lower than about 80 °C, preferably at around 70 °C. In this case, a temperature lower than about 50 °C would cause the dry out at the anode side due to the fact that the maximum water supply amount $J_{A(MAX)}$ at the anode side is less than the water transportation amount J_M . Thus, it is desirable to operate the fuel cell between about 50 °C and 80 °C.

Thickness of the polymer electrolyte membrane

Referring to Figure 4, it is shown a fuel cell output characteristics as the air supply amount and the operating condition are changed. Membranes with the thickness of 100 and 50 μm are employed. The current density is 5A/cm² and the fuel cell output characteristics is provided as a cell output voltage for a single fuel cell structure.

According to Figure 4, the membrane with 50 μm thickness exerts a greater output voltage or as the membrane is thin, the fuel cell generates a greater voltage. As the operating temperature increases, the cell performance is reduced. This is because the dry out would occurs at the cathode side. As aforementioned, it is easy to establish the water balance between the anode side and the cathode side as the membrane

becomes thin. Therefore, in this respect, it is desirable to make the membrane thin. However, if the membrane thickness is smaller than about 20 μm , there would occur a substantial gas leak across the membrane. As a result, the cell performance is deteriorated. Thus, it would be desirable that the thickness of the membrane is ranged from about 20 μm to 80 μm , preferably 20 μm to 50 μm .

Figure 5 shows the change of the internal resistance of the fuel cell as the gas flow rate is changed at the operating temperature 60 °C of the fuel cell. It is found that as the membrane becomes thin, the internal resistance gets reduced and thus preferable to the fuel cell.

Thickness of the catalyst layer

The cell performance depends on how high voltage can be produced. This can be accomplished by suppressing an overpotential of mass transport region due to a higher current density. The overpotential can be suppressed by reducing the thickness of a reaction region or catalyst layer and can enhance the limiting current density.

By reducing the thickness of the reaction region, a higher reaction efficiency and higher cell performance can be maintained even under a lower partial pressure of oxygen. In other words, it is possible to operate the fuel cell system with a low air compression condition and reduce a driving power of an air compressor. According to the research of the present inventors, a desirable cell performance can be obtained when the catalyst layer has about 10 μm in thickness. The catalyst layer can be formed by carrying platinum catalytic particles of about 2-4nm in size or diameter on carbon black particles of about 100 nm in size, or diameter.

Where the catalyst layer has about 10 micron in thickness, the weight ratio of platinum particles to the carbon black is about 2 to 1. As the catalyst gets thin, the weight ratio of the platinum catalytic particles increases. However, while the platinum catalytic particles are maintained at the desirable sizes as mentioned above, the catalyst layer is formed. In this case, the weight ratio of the platinum to the carbon black is at most about 60%.

In view of this, a limit thickness of the catalyst layer would be about 10 μm . A smaller catalyst layer will not be able to maintain the desirable size ranges of the platinum particles.

Where the catalyst layer is formed with about 10 \pm about 5 μm in thickness and the total polymer electrolyte membrane is formed with about 20 \pm about 10 μm , the fuel cell can be operated with about 0.15 MPa of the reaction gas pressure without deteriorating the cell performance. Such material for forming the catalyst layer with about 10 μm can be available from Japan Goretex Incorporated in Japan.

Fuel cell system of a preferred embodiment

Figure 6 shows a schematic view of a fuel cell system in accordance with a preferred embodiment of the present invention similar to Figure 1.

The fuel cell system shown in Figure 6 is the same as Figure 1 except that the fuel cell in Figure 6 is not provided with the air humidifier.

Figure 7 shows fuel cell characteristics or cell performance of the fuel cell system according to the present invention as shown in Figure 6 as the operating temperature is changed.

In this embodiment, the polymer electrolyte membrane has about 20 μm .

Based on the result of Figure 6, it is found that as the operating temperature decreases, the cell performance is improved. In particular, as the operating temperature increases, the cell performance is deteriorated in a low current density range. In the low current density range, a stoichiometric flux is reduced, and thus the air utilization factor is relatively reduced to increase the water amount taken away from the cathode side. This causes the dry out at the cathode side.

Referring to Figure 8, there are shown the cell performances for the conventional fuel cell with an air humidifier as shown in Figure 1 and the fuel cell without an air humidifier in accordance with the present invention as shown in Figure 6 when the operating temperature is 60 °C.

According to this result, it is found that there is no deterioration of the cell performance with regard to the fuel cell without air humidifier. Namely, it is possible to operate the fuel cell without humidifying the air and there is no need to dispose the air humidifier in the present invention. As shown in Figure 7, a higher cell performance can be obtained without the air humidifier in a higher current density condition.

In Figure 9, it is shown a cell performance of a fuel cell employing 200cm² x 60 cell stacks without air humidification. In this case, the hydrogen pressure is about 0.15 MPa. As shown in Figure 9, the fuel cell generated 3.9KW in output power and 0.31 KW/l in output power density.

Although the present invention has been explained with reference to a specific, preferred embodiment, one of ordinary skill in the art will recognize that modifications and improvements can be made while remaining within the scope and spirit of the present invention. The scope of the present invention is determined solely by the appended claims.

Claims

1. A polymer electrolyte fuel cell comprising;

a polymer electrolyte membrane,
an anode catalytic electrode disposed at one side of the polymer electrolyte membrane,

a fuel gas being supplied to the anode catalytic electrode,

a cathode electrode disposed at another side of the polymer electrolyte,

an oxidation gas being supplied to the cathode catalytic electrode, and,

water control means for controlling a reduction amount of water from the cathode electrode together with the oxidation gas to a sum of a water amount increased at the cathode electrode by being transported from the anode electrode through the polymer electrolyte membrane during a redox reaction of the fuel cell and a water amount produced by an oxidation reaction in the cathode electrode.

2. A polymer electrolyte fuel cell as recited in claim 1 wherein the polymer electrolyte membrane has a thickness of about 20 -80 μm .

3. A polymer electrolyte fuel cell as recited in claim 1 wherein the polymer electrolyte membrane has a thickness of about 20-50 μm .

4. A polymer electrolyte fuel cell as recited in claim 1 wherein an operating temperature of the fuel cell is maintained from about 50 C° to 80 C°

5. A polymer electrolyte fuel cell as recited in claim 1 wherein an operating temperature of the fuel cell is maintained at about 60 C°-70 C°.

6. A polymer electrolyte fuel cell as recited in claim 1 wherein the fuel gas is a hydrogen and the oxidation gas is an air.

7. A polymer electrolyte fuel cell as recited in claim 1 wherein the polymer electrolyte membrane is formed with catalyst layers at opposite side, each of the catalyst layer being about 10 μm in thickness.

8. A polymer electrolyte fuel cell as recited in claim 7 wherein the catalyst layer carries platinum catalytic particles of about 2-4 nm in size on carbon black particles of about 100 nm in size.

9. A polymer electrolyte fuel cell as recited in claim 1 wherein no oxidation gas humidifier is provided.

10. A polymer electrolyte fuel cell comprising;

a polymer electrolyte membrane,

an anode catalytic electrode disposed at one side of the polymer electrolyte membrane,

a fuel gas being supplied to the anode catalytic electrode,

a cathode electrode disposed at another side of the polymer electrolyte,

an oxidation gas being supplied to the cathode catalytic electrode,

the polymer electrolyte membrane being formed with about 20 μm -80 μm in thickness, and

an operating temperature of the fuel cell being maintained at about 50 C°-70 C°.

11. A polymer electrolyte fuel cell as recited in claim 10 wherein the fuel gas is a hydrogen and the oxidation gas is an air.

12. A polymer electrolyte fuel cell as recited in claim 10 wherein the polymer electrolyte membrane is formed with catalyst layers at opposite side, each of the catalyst layer being about 10 μm in thickness.

13. A polymer electrolyte fuel cell as recited in claim 12 wherein the catalyst layer carries platinum catalytic particles of about 2-4 nm in size on carbon black particles of about 100 nm in size.

14. A polymer electrolyte fuel cell as recited in claim 10 wherein no oxidation gas humidifier is provided.

15. A polymer electrolyte fuel cell comprising;

a polymer electrolyte membrane, an anode catalytic electrode disposed at one side of the polymer electrolyte membrane,

a fuel gas being supplied to the anode catalytic electrode,

a cathode electrode disposed at another side of the polymer electrolyte,

an oxidation gas being supplied to the cathode catalytic electrode, and,

temperature control means for controlling a fuel cell operating temperature so that a water supply amount at the anode catalytic electrode is greater than a water amount transported from the anode electrode through the polymer electrolyte membrane during a redox reaction of the fuel cell.

16. A polymer electrolyte fuel cell as recited in claim 15 wherein the polymer electrolyte membrane has a thickness of about 20 -80 μm .

17. A polymer electrolyte fuel cell as recited in claim 15 wherein the polymer electrolyte membrane has a thickness of about 20-50 μm .

18. A polymer electrolyte fuel cell as recited in claim 15 wherein an operating temperature of the fuel cell is maintained at about 50 C° to 80 C°

19. A polymer electrolyte fuel cell as recited in claim 15 wherein an operating temperature of the fuel cell is

maintained at about 60 C°-70 C°.

20. A polymer electrolyte fuel cell as recited in claim 15
wherein the fuel gas is a hydrogen and the oxidation gas is an air. 5
21. A polymer electrolyte fuel cell as recited in claim 15
wherein the polymer electrolyte membrane is formed with catalyst layers at opposite side, each of the catalyst layer being about 10 µm in thickness. 10
22. A polymer electrolyte fuel cell as recited in claim 21
wherein the catalyst layer carries platinum catalytic particles of about 2-4 nm in size on carbon black particles of about 1000 nm in size. 15
23. A polymer electrolyte fuel cell as recited in claim 1 further comprising temperature control means for controlling a fuel cell operating temperature so that a water supply amount at the anode catalytic electrode is greater than a water amount transported from the anode electrode through the polymer electrolyte membrane during a redox reaction of the fuel cell. 20
24. A polymer electrolyte fuel cell as recited in claim 23
wherein the polymer electrolyte membrane has a thickness of about 20 -80 µm. 25
25. A polymer electrolyte fuel cell as recited in claim 24
wherein an operating temperature of the fuel cell is maintained at about 60 C°-70 C°. 30
26. A polymer electrolyte fuel cell as recited in claim 23
wherein the fuel gas is a hydrogen and the oxidation gas is an air. 35
27. A polymer electrolyte fuel cell as recited in claim 23
wherein no oxidation gas humidifier is provided. 40
28. A polymer electrolyte fuel cell as recited in claim 23
wherein the polymer electrolyte membrane is formed with catalyst layers at opposite side, each of the catalyst layer being about 10 µm in thickness. 45
29. A polymer electrolyte fuel cell as recited in claim 28
wherein the catalyst layer carries platinum catalytic particles of about 2-4 nm in size on carbon black particles of about 100 nm in size. 50
30. A polymer electrolyte fuel cell comprising;

a polymer electrolyte membrane,
an anode catalytic electrode disposed at one side of the polymer electrolyte membrane, 55
a fuel gas being supplied to the anode catalytic electrode,
a cathode electrode disposed at another side

of the polymer electrolyte,

an oxidation gas being supplied to the cathode catalytic electrode, and,
water amount control mechanism which controls a reduction amount of water from the cathode electrode together with the oxidation gas to a sum of a water amount increased at the cathode electrode by being transported from the anode electrode through the polymer electrolyte membrane during a redox reaction of the fuel cell and a water amount produced by an oxidation reaction in the cathode

31. A polymer electrolyte fuel cell as recited in claim 30
wherein the polymer electrolyte membrane has a thickness of about 20 -80 µm.
32. A polymer electrolyte fuel cell as recited in claim 31
wherein an operating temperature of the fuel cell is maintained at about 60 C°-70 C°.
33. A polymer electrolyte fuel cell as recited in claim 30
wherein the fuel gas is a hydrogen and the oxidation gas is an air.
34. A polymer electrolyte fuel cell as recited in claim 30
wherein no oxidation gas humidifier is provided.
35. A polymer electrolyte fuel cell as recited in claim 30
wherein the polymer electrolyte membrane is formed with catalyst layers at opposite side, each of the catalyst layer being about 10 µm in thickness.
36. A polymer electrolyte fuel cell as recited in claim 35
wherein the catalyst layer carries platinum catalytic particles of about 2-4 nm in size on carbon black particles of about 100 nm in size.

FIG. 1

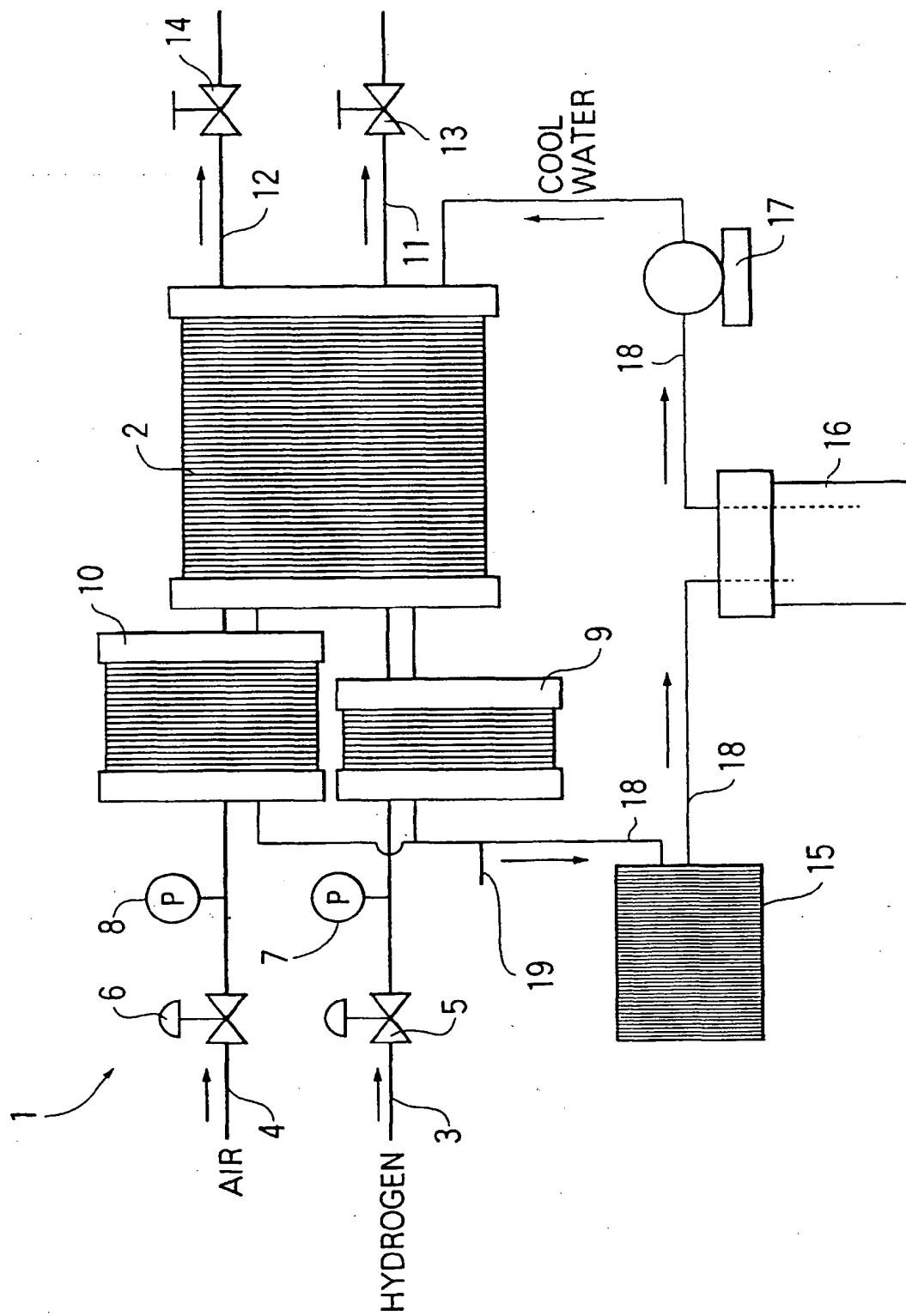
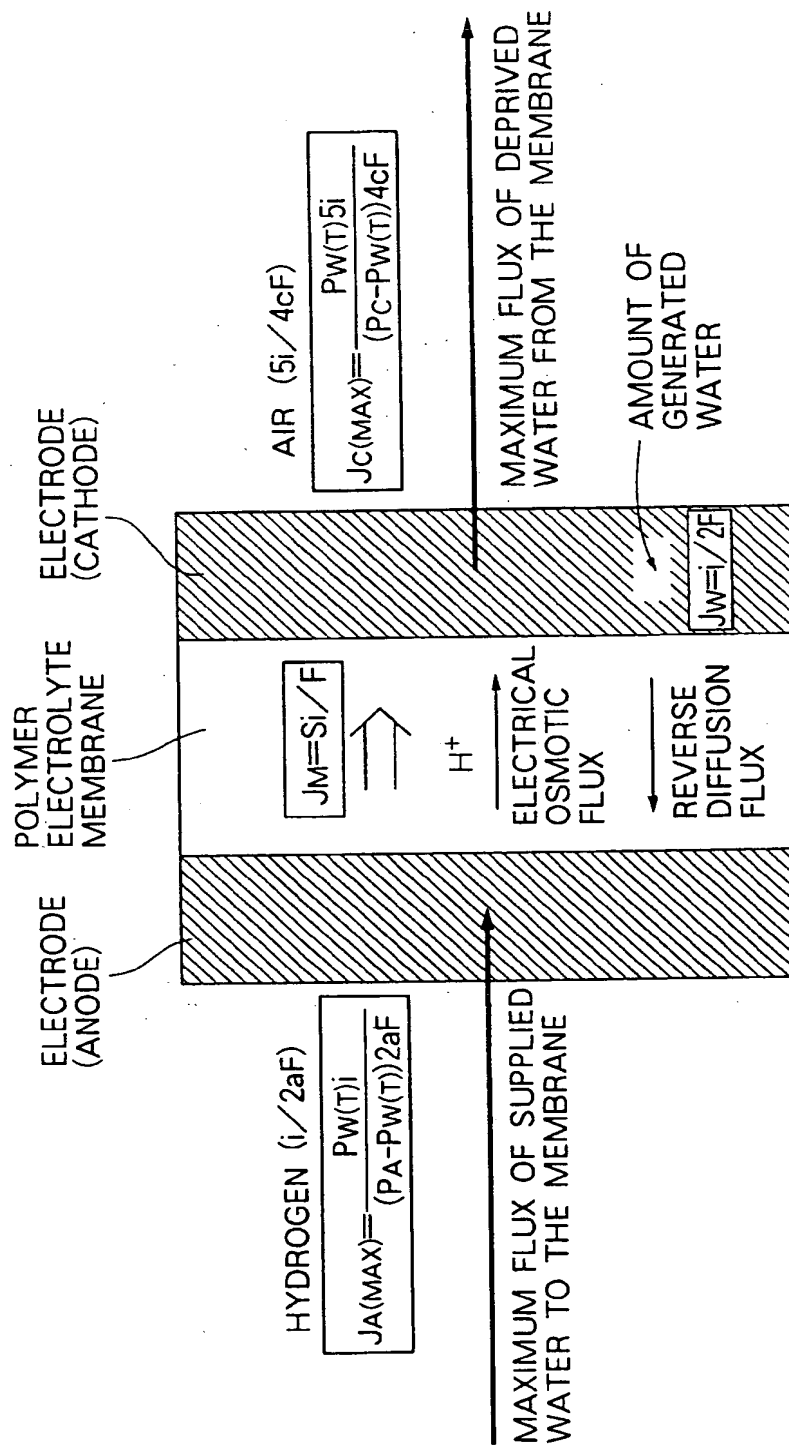


FIG. 2



S: NET FLUX OF WATER PER A MOLE OF ELECTRONS
 F: FARADAY CONSTANT
 i: CURRENT DENSITY
 a: UTILIZATION FACTOR OF HYDROGEN
 c: UTILIZATION FACTOR OF AIR
 P_A: TOTAL PRESSURE OF ANODE SIDE (HYDROGEN)
 P_C: TOTAL PRESSURE OF CATHODE SIDE (AIR)
 P_W(T): SATURATION VAPOR PRESSURE AT TEMP. OF T(°C)

FIG. 3

WATER TRANSPORTATION RATIO BASED ON NET FLUX OF WATER
PER MOLE OF ELECTRONS

°C	SATURATION VAPOR PRES.	SATURATION VAPOR PRES.	J _m	J _a (max) a=0.5	J _m +J _w	J _c (max) c=0.5
	atm	mmHg				
40	0.0728	55.33	0.10	0.05	0.60	0.13
50	0.1218	92.57	0.10	0.09	0.60	0.22
60	0.1966	149.42	0.10	0.15	0.60	0.38
70	0.3076	233.78	0.10	0.26	0.60	0.64
80	0.4674	355.22	0.09	0.45	0.59	1.13
90	0.6919	525.84	0.09	0.86	0.59	2.14

ELECTROLYTE: Aciplex-1002
HYDROGEN PRESSURE: 0.15MPa
AIR PRESSURE: 0.15MPa

FIG. 4

THE CHARACTERISTICS OF CELL
VOLTAGE WITH THE AIR FLOW
AT CURRENT DENSITY OF $0.5\text{A}/\text{cm}^2$

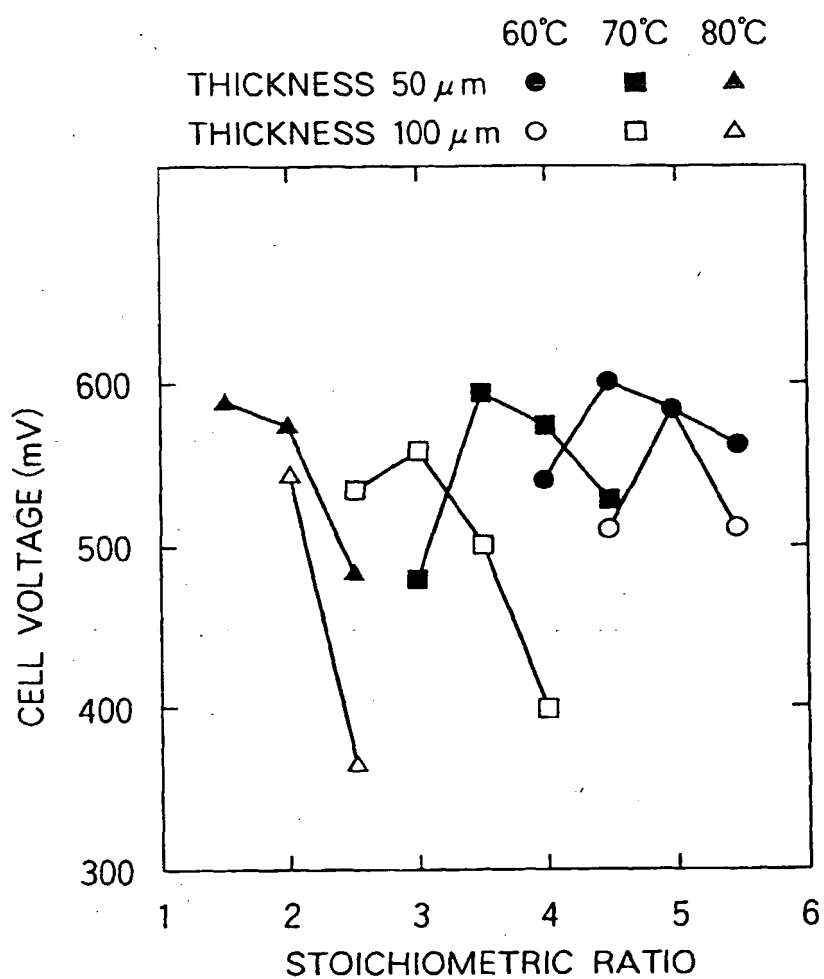


FIG. 5

THE CHARACTERISTICS OF CELL
INTERNAL RESISTANCE WITH AIR
FLOW AT CELL TEMPERATURE OF 60°C

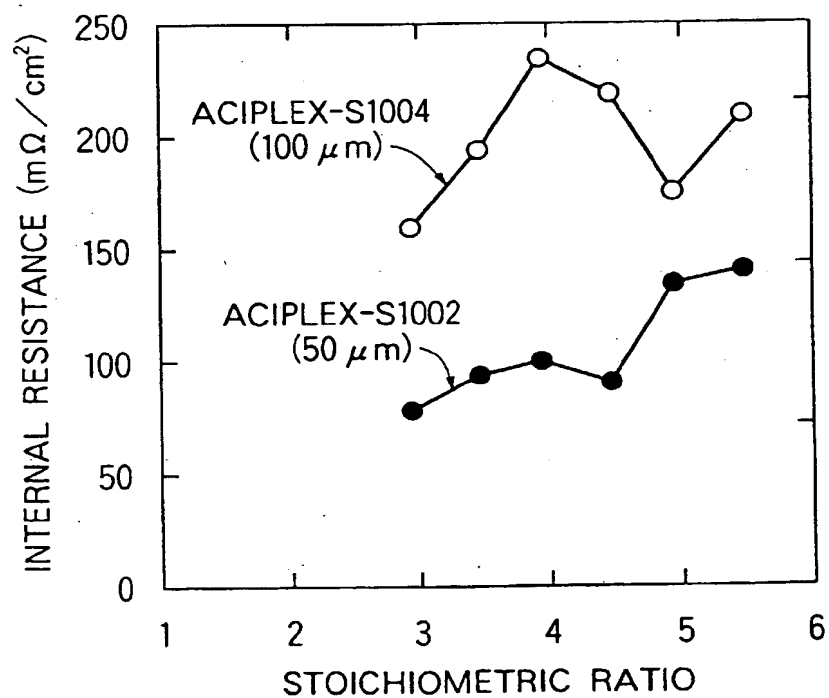


FIG. 6

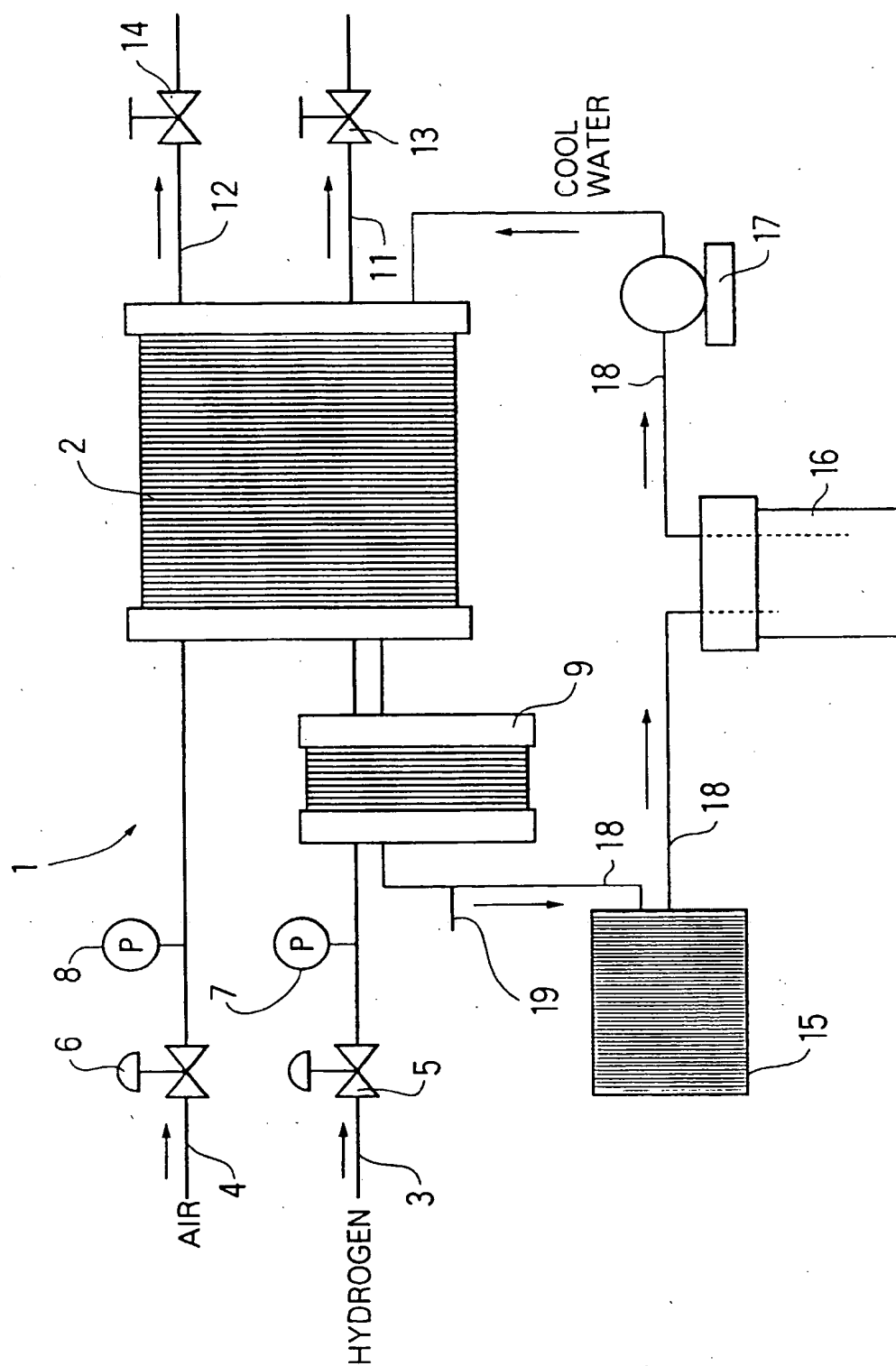


FIG. 7

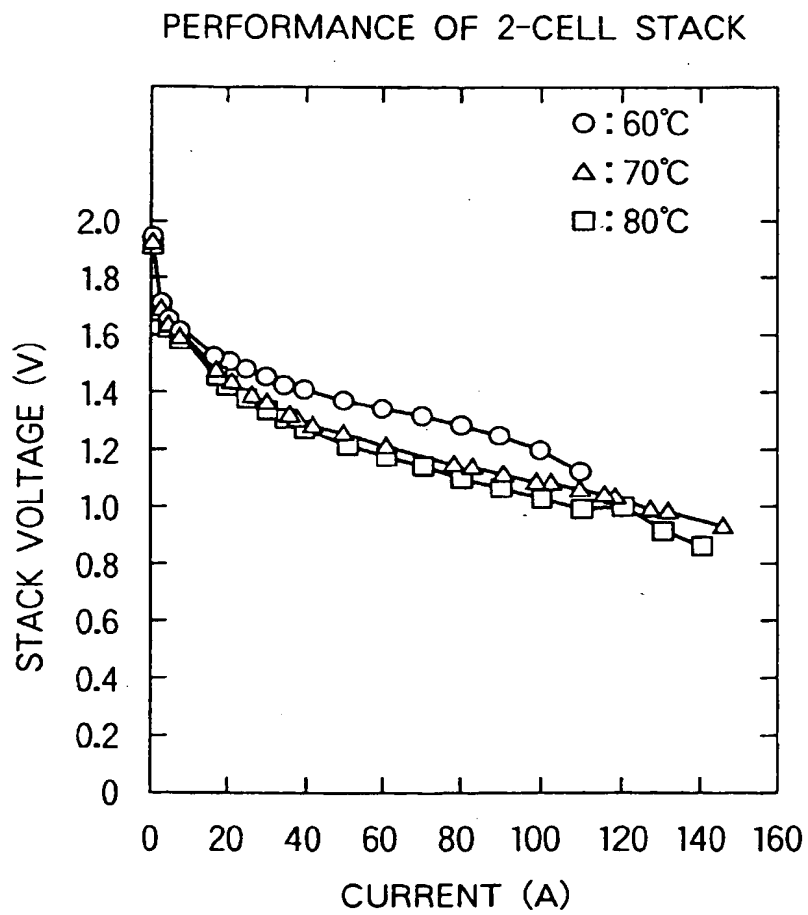


FIG. 8

PERFORMANCE OF 2-CELL STACK AT 60°C

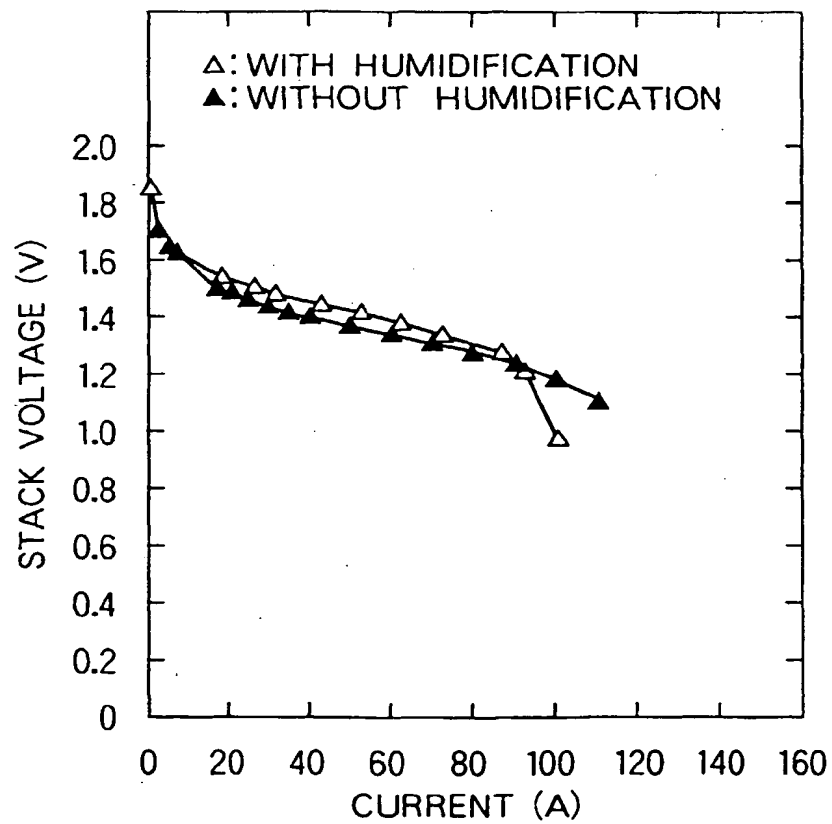
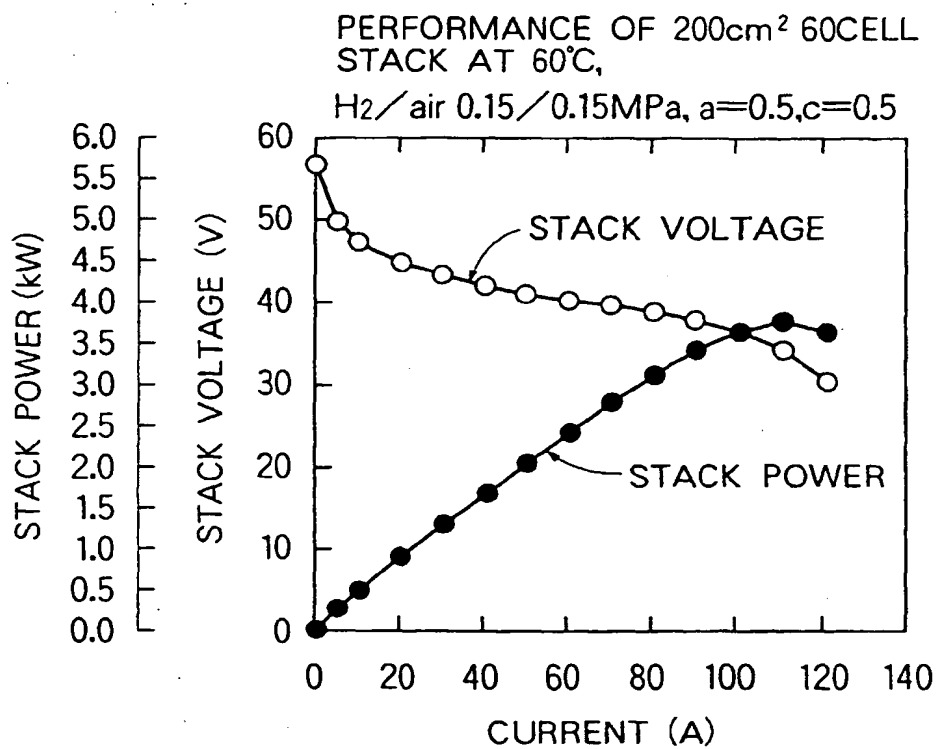


FIG. 9





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 10 8642

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	VOSS H H ET AL: "Anode water removal: a water management and diagnostic technique for solid polymer fuel cells" ELECTROCHIMICA ACTA, vol. 40, no. 3, February 1995, page 321-328 XP004020026	1-6,10, 11, 15-20, 23-27, 30-34	H01M8/04
Y	* Page 322, left hand column, second paragraph * * Page 323, Figure 3 * * Pages 325, 328, Figure 11 *	21,22, 25,28, 29,35,36	
X	MIACHON S ET AL: "Internal hydration H2/O2 100 cmpolymer electrolyte membrane fuel cell" JOURNAL OF POWER SOURCES, vol. 56, no. 1, July 1995, page 31-36 XP004044363	1-4,6,9, 30,31, 33,34	
Y	* Pages 32 - 34: 3. Experimental; 4. Results *	7,8, 10-20, 23-27, 32,34	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
Y	US 5 234 777 A (WILSON MAHLON S) 10 August 1993 * figures 2,3 * * column 8, line 44-66 *	7,8,12, 13,21, 22,28, 29,35,36	H01M
The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 30 July 1998	Examiner Engl, H
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document</p>			

EPO FORM 1503 03/82 (P04C01)



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EUROPEAN SEARCH REPORT

Application Number
EP 98 10 8642

DOCUMENTS CONSIDERED TO BE RELEVANT				
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)	
Y	MOSDALE R ET AL: "Water profile determination in a running proton exchange membrane fuel cell using small-angle neutron scattering" JOURNAL OF MEMBRANE SCIENCE, vol. 118, no. 2, 18 September 1996, page 269-277 XP004041808 * Pages 272-275: 3. Results and discussion *	1-3, 10-14, 19,30-36		
Y	WILSON M S ET AL: "Low platinum loading electrodes for polymer electrolyte fuel cells fabricated using thermoplastic ionomers" ELECTROCHIMICA ACTA, vol. 40, no. 3, February 1995, page 355-363 XP004020030 * Page 358, left hand column *	1-3,10, 11, 15-17, 23,24, 30,31,33		
A	MOSDALE R ET AL: "Analysis of performance and of water and thermal management in proton exchange membrane fuel cells" ELECTROCHIMICA ACTA, vol. 40, no. 4, March 1995, page 413-421 XP004020007 * page 419 - page 420 *	1,10,15, 30		TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	US 5 441 819 A (VOSS HENRY H ET AL) 15 August 1995 * the whole document *	1,10,30		
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The present search report has been drawn up for all claims				
Place of search MUNICH		Date of completion of the search 30 July 1998	Examiner Engl, H	
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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP 0 631 337 A (TANAKA PRECIOUS METAL IND ; WATANABE MASAHIRO (JP)) 28 December 1994	1-4,6,9, 30,31, 33,34	
Y	* column 9, line 2 - column 10, line 26 *	10,11, 14-18, 20,23, 24,26,27	
A	* column 2, line 21-27 * ----- EP 0 718 903 A (JAPAN GORE TEX INC) 26 June 1996 * examples 7-9 * -----	7,13,21, 35	
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Place of search MUNICH		Date of completion of the search 30 July 1998	Examiner Engl, H
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